

# JCAB English Test and ATC Communications Speech Speeds

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## Abstract

We measured the speech speed rate in the listening comprehension section of the Japanese Language Proficiency Certification test for pilots as established by the Japanese Civil Aviation Bureau in conformance with the requirements of the International Civil Aviation Organization, and found a median of 4.5 syllables per second. We compare this rate with the median of 6.1 syllables per second in actual ATC communications and of 5.1 and 4.7 syllables per second respectively in movies and TV news which we determined in previous studies, and of 5-7 syllables per second in typical everyday speech. We conclude that the pilot test and the ICAO recommendations are slower than speaking rates in real-life situations. We note that in a previous study we found that errors in listening to TV show sentences increased 5-fold between 4 syllables per second and 6 syllables per second, so that even very highly-rated non-native speakers of English missed 21.2% of the words at 6 syllables per second and 32.7% at 7 syllables per second, despite repeated listening.

We express our concern that even highly-rated pilots will similarly perform poorly in listening to fast speech. We call for further studies on the effects of increasing speech rates on the listening ability of pilots, in order to contribute to the development of training material and safer air travel.

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## 1. Introduction

Language misunderstandings and errors have sometimes been responsible or partly responsible for air traffic fatalities. The International Civil Aviation Organization (ICAO, <http://www.icao.int/>), the agency of the United Nations which sets standards and regulations for aviation safety and security, reported :

Between 1976 and 2000, more than 1100 passengers and crew lost their lives in accidents in which investigators determined that language problems had played a contributory role. Moreover, numerous incidents involving language issues, including a number of runway incursions, are reported annually (ICAO Regional Airspace Safety Monitoring Advisory Group 2004).

Such tragic incidents led the ICAO to call for higher proficiency levels in English language (ICAO 2004, p.6), and in 2003 adopted Annex 1 Amendment 164 outlining Proficiency Requirements in Common English. Since the requirements came into effect in March 2008, pilots on international flights must demonstrate language proficiency in either English or the language used by the station on the ground, and air traffic controllers (ATCO) working on stations serving designated airports and routes used by international air services must demonstrate language proficiency in English as well as in any other language(s) used by the station on the ground.

The minimum requirement for English language ability is ICAO Language Proficiency Rating Scale Level 4 (Operational Level) (ICAO Flight Safety Section c2011). ICAO Operational Level 4 is a measure of ability to communicate in English on topics related to aviation work, graded by (1) the accuracy of pronunciation, (2) ability in relevant grammatical structures and sentence patterns, (3) vocabulary range and accuracy, (4) fluency (ability to produce stretches of language at an appropriate tempo), (5) accurate comprehension on common, concrete, and work-related topics, and (6) interaction ability (ability to give immediate, appropriate, and informative responses).<sup>1)</sup>

In compliance with this rule, Japanese pilots on international routes must obtain a Language Proficiency Certification as established by the Japanese Civil Aviation Bureau (JCAB) of the Ministry of Land, Infrastructure, Transport and Tourism (<http://www.mlit.go.jp/en/index.html>), to demonstrate that their ability to speak and understand the English used for radiotelephony communications between pilots and ATCO is at least ICAO Level 4.

Tenma & Kelly (2007) describe how the major Japanese airlines JAL and ANA were designated by the Japanese government in 2005 to develop and operate a language testing system to evaluate some 5,500 pilots in time to meet the effective starting date of the ICAO rule. They explain that pilots who are judged to be already above Level 4 are exempt from the tests, as are pilots who graduate from authorized training organizations or the Civil Aviation College where English language training programs are in place. At the present time, Level 4 and 5 pilots will need to be re-evaluated every 3 years, rather than the 6 years as established by the ICAO.

The listening component of the test consists of 14 Air Traffic Control (ATC) dialogues between ATCO and pilots, comprised of several sentences chosen from a database. Test-takers, using a computer, must answer 3 questions about each dialogue by choosing from multiple-choice answers. They may take notes while listening. An example test question is in the Appendix below. Pilots obtaining a score of over 70% can continue with the interview component, which consists of (1) warm up, (2) single picture card description, (3) ATC role play and its description, (4) sequence picture card description, and (5) wind down (Tenma & Kelly 2007, p.2).

In the present study, we measure the speed rate of the speech in the listening comprehension test of the Japanese Language Proficiency Certification System for Pilots. We then analyze the speed rate compared with the speed rate of actual ATC communications which we measured in a previous study. We then discuss how the speed rate in the pilot's test compares with rates in various other sources, to see if the test may be considered appropriate or valid as far as speed rate is concerned.

2. Method

We analyzed 14 dialogues, totaling 130 sentences, from the JCAP Language Proficiency Certification test for Japanese pilots of July 2011, which are publicly available at [http://www.mlit.go.jp/page/kanbo01\\_hy\\_001647.html](http://www.mlit.go.jp/page/kanbo01_hy_001647.html)

The sentences were analyzed to determine their speeds using a method identical to our previous studies measuring speech speed in ATC communications in the USA (Nitta, Okazaki & Klinger 2011) and in popular movies and other media (Nitta, Okazaki & Klinger 2010a). A detailed description of the method is available in those articles; in brief, we counted the number of syllables in each sentence, measured the length of the sentences in seconds to two decimal places with the WaveSurfer software, and, from these measurements, calculated the rate of speech speed (the articulation rate), as measured in syllables per second (sps).

3. Results

Figure 1 shows the result of our measurement of the articulation rate of the spoken dialogues in the Language Proficiency Certi-

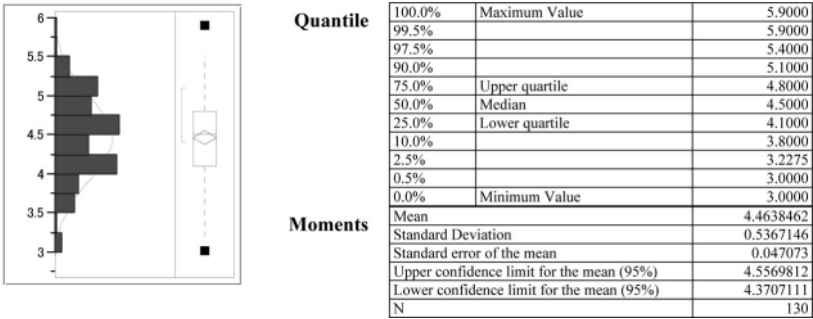


Figure 1. Speech Rates of the Language Proficiency Certification Test for Japanese Pilots, Listening Comprehension Section.

fication test for Japanese pilots of July 2011. The median rate is 4.5 sps in a distribution of 3.5 - 5.5 sps.

## 4. Discussion

### 4a. Comparison with ATC communications.

How does the pilot test speech rate compare with actual ATC communication rates? In Nitta, Okazaki & Klinger (2011) we analyzed 4,006 sentences of radio transmissions from 2008-2009 between pilots and ATCO and pilots and ground crews at Los Angeles International Airport (LAX), San Francisco International Airport (SFO), and Honolulu International Airport (HNL). We found a median rate of 6.1 sps in ATC speech, with a distribution of 4 to 8 sps.<sup>2)</sup>

Figure 2 (from Nitta, Okazaki & Klinger, 2011) shows the result of our measurement of the articulation rate of ATC communications.

We performed a One-Way Analysis of Variance with the data from the Proficiency Test and the ATC communications, as shown in Figure 3. We find that the rates of speech in the Proficiency Test and in ATC speech movie show a statistically significant difference.

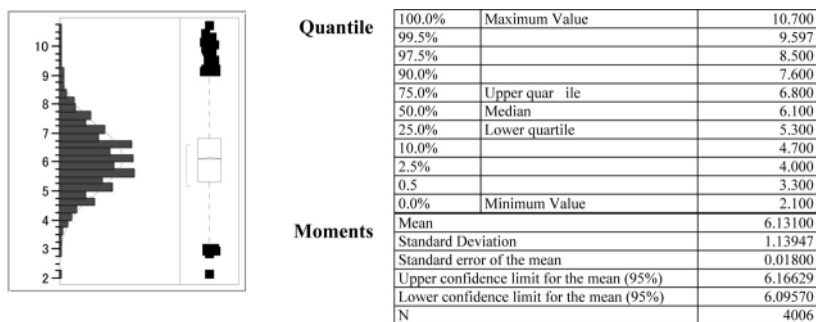


Figure 2. ATC Speech Rates (including Pilot & Ground Crew Transmissions).

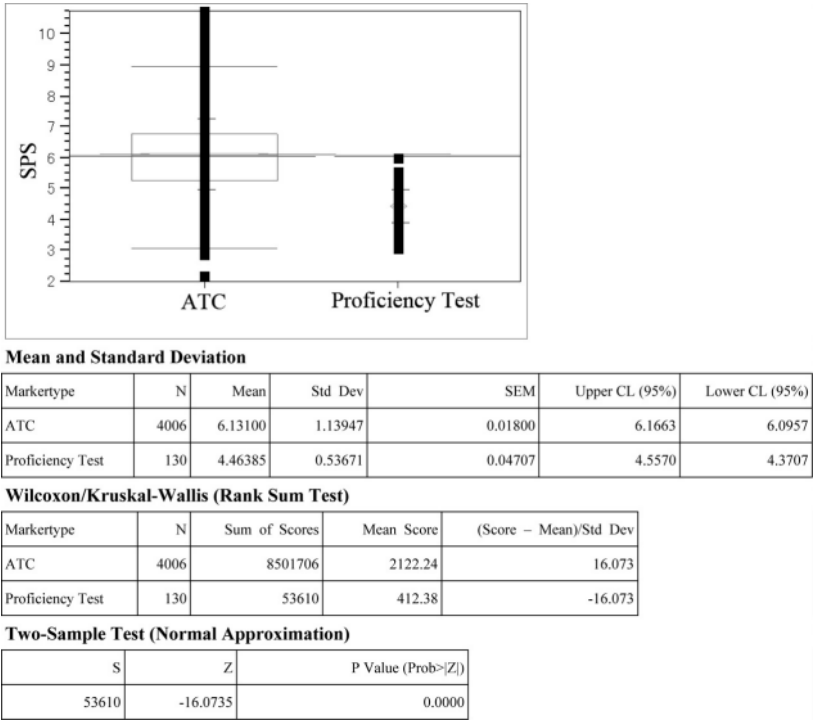


Figure 3. One-Way Analysis of Variance.

From this comparison with speaking rates in actual ATC communications, we consider the pilot proficiency test speech rate of 4.5 sps to be at an intermediate level, considerably slower than regular ATC speech.

A fast rate of speech is a prominent characteristic of ATC communication, particularly when compared to movie speech speeds and everyday speech speeds. ATC speech is typically routine and unremarkable, with standardized and fairly limited vocabulary, so the repetition of conventional vocabulary no doubt makes it easier for pilots to become familiarized with it and so understand speech at high rates. However, we have received many personal com-

ments from Japanese pilots on international routes that they find that ATC communication is often too fast for comfort. The rate of 6.1 sps which we found in actual ATC transmissions supports their claims.

#### **4b. Comparison with Everyday Speech & Movie Speech.**

How does the pilot test speech rate of 4.5 sps compare with other speech rates? Robb et al. (2004) lists a number of research works demonstrating that adult speakers of American English have an articulation rate of about 5.3 sps. Kendall (2009, Table 6.5.1) found European Americans speaking at a rate of 5.25 sps.

In Nitta, Okazaki & Klinger (2010a), we measured rates in movies and other spoken media. The rate of 4.5 sps in the 130 sentences in the pilot's test is slower than the median rate of 5.1 sps we found in 10,963 sentences in 11 popular movies and TV dramas. The median ranged from 4.3 sps to 5.8 sps among these movies, with only one being slower than 4.5 sps.<sup>3)</sup> The rate of 4.5 sps is faster than the rate of 2.9 sps we found in 259 sentences in a story read for children, "Frog and Toad Together". 4.5 sps is faster than the median of 3.2 sps in 257 sentences in VOA Special English for non-native speakers of English, and slower than the 4.7 sps in 398 sentences in regular VOA and CNN news.

4.5 sps is much slower than the 6 sps Maeda (2000) measured in some CNN interviews. Maeda (2000) also measured ranges of 3.53-4.24 sps in four English language learning media products produced for Japanese junior high school classes, ranges of 4.09-4.86 in five "false beginner" products, and ranges of 4.59-5.02 in three intermediate educational products.

From these comparisons of speaking rates, we consider the pilot proficiency test speech rate of 4.5 sps to be at an average or intermediate level, somewhat slower than usual conversational speech and regular newscasts, and somewhat faster than newscasts and educational products for English learners.

#### **4c. Effects of Increasing Speech Rates on Listening Ability.**

How is listening ability affected as speech speeds increase? Ki-

noshita (2009), in a book on improving listening comprehension, discusses how English sounds change at increasing rates of speed, and mentions that Japanese students and speakers of English often have trouble understanding daily conversation by native speakers and movie speech at fast speeds. In Nitta, Okazaki & Klinger (2010 b), we analyzed the effect on hearing English spoken at increasingly fast speeds. We used 60 sentences from three American TV shows (*Friends*, *Sex and the City*, and *Beverly Hills 90210*) which we divided into groups of 12 sentences spoken at 5 different rates of speed as measured in sps.<sup>4)</sup> The subjects were 31 non-native speakers of English (NNSE) and 31 native speakers of English (NSE). The NNSE were very high-level Japanese speakers of English, all of whom had over 860 points in their TOEIC<sup>®</sup> scores, with an average score of 923.3, and who had an average of 3.5 years of overseas residence in English-environment countries. All of the subjects were allowed to listen to the sentences any number of times, until they were satisfied with what they could hear, and then record by typing what they heard. The NNSE also translated what they heard into Japanese. A few words which were unknown to the NNSE in written form were eliminated from the results.

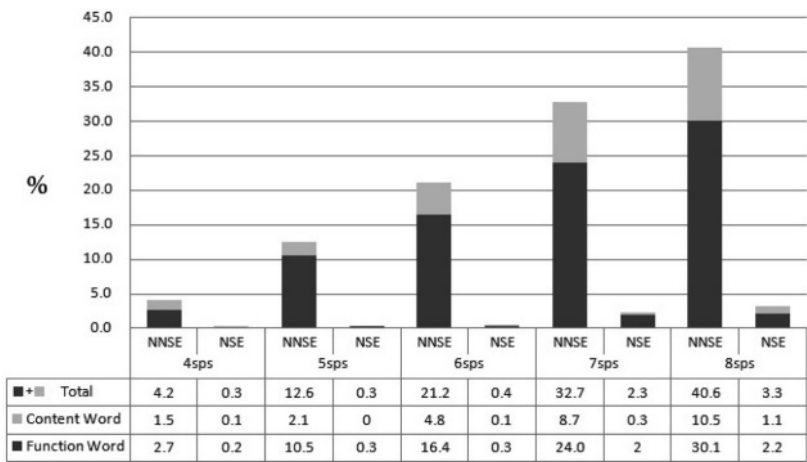


Figure 4. Missed Word Rates at Different Speech Speeds.



The study evaluated listening ability to “decode” the heard sentences, rather than evaluating listening “comprehension.” The experiment recorded only the number of words that were missed or misheard; it did not evaluate the subjects’ comprehension of the heard sentences. The experiment could not claim to determine how much comprehension decreases as speech speeds increase. To obtain a statistically valid result of how much comprehension decreases, all of the sentences would have to have been repeated at all of the different speech rates.

In the study, the subjects could listen to the sentences repeatedly, and they did so up to 10 times for each sentence at high speed rates. This is quite unlike a real-life situation, including ATC situations, where at best, you might ask a speaker to repeat a sentence once or twice. In the pilot test, test-takers could only listen once. Nonetheless, the 2010b study provides some evidence of how drastically hearing ability decreases as speed rates increase, even for NNSE who are highly rated by English ability standards.

Figure 4 (from Nitta, Okazaki & Klinger 2010b) shows the percentage of words that were missed or mistaken at different speech rates.

Figure 4 shows that, at 4 sps, the NNSE subjects missed or mistook 4.2% of the words, of which 2.7% were function words and 1.5% were content words (i.e., out of 100 words, 4.2 were misheard). At 5 sps, the Missed Word Rate (MWR) jumped to 12.6%; 10.5% function words and 2.1% content words. At 6 sps, the MWR was 21.2%; 16.4% function words and 4.8% content words. At 7 sps, the MWR was 32.7%; 24% function words and 8.7% content words. At 8 sps, the MWR was 40.6%; 30.1% function words and 10.5% content words. The NSE missed very few words even at a very high speech rate of 8 sps.

At 4.5 sps, the missed word rate is probably somewhat lower than half-way between 4 sps and 5 sps, or somewhat lower than 8.4%. We cannot however suppose that this figure would also apply to the pilot proficiency test median rate of 4.5 sps. The proficiency test does not have the wide variety of vocabulary items and individual personal accents as TV shows and movies and personal conver-

sation do. We therefore suppose that there was very little mishearing of word items in the pilot's proficiency test at 4.5 sps, and that the speech rate was not much of a burden on listening ability.

This 2010b study found that there is a large difference in hearing at 4.5 sps and at 6sps, so that words, which may be understandable at 4.5 sps, are not heard or are misheard at 6 sps. When we consider that we found a missed word rate of 21.2% at 6.0 sps even for very high-level NNSE who had the opportunity to listen repeatedly to the sentences, we suppose that there will be much more mishearing of vocabulary by Japanese pilots when they listen to ATC sentences at the median rate of American ATC communications of 6.1 sps. In our future research, we hope to investigate what happens to hearing at that rate for pilots listening to ATC communications, and what kinds of errors particularly arise.

#### **4d. ICAO Recommendation for Speaking Rate**

What rate of speech speed does the ICAO recommend? The ICAO says that ATC communications should be clear and distinct and at an even rate of under 100 words per minute. The "ICAO Annex 10 AERONAUTICAL TELECOMMUNICATIONS, VOLUME II, International Standards and Recommended Practices and Procedures for Air Navigation Services, 5.2.1.5 Transmitting technique" recommends (the underlines are added by us) :

5.2.1.5.3 PANS. Speech transmitting technique should be such that the highest possible intelligibility is incorporated in each transmission. Fulfillment of this aim requires that air crew and ground personnel should :

- a) enunciate each word clearly and distinctly ;
- b) maintain an even rate of speech not exceeding 100 words per minute. When a message is transmitted to an aircraft and its contents need to be recorded the speaking rate should be at a slower rate to allow for the writing process. A slight pause preceding and following numerals makes them easier to understand ;
- c) maintain the speaking volume at a constant level.

For a general description of speaking speed, words per minute (wpm) is often conveniently used. For example, there are many anecdotes about the famous TV news anchor Walter Cronkite training himself to deliver the news at a rate of 124 words per minute. However, for language research involving measuring speech speed, wpm is too inexact, as words have different number of syllables depending on the context. The number of syllables in 100 words can range from 123 syllables in the case of children, who typically use short one-syllable or two-syllable words (Flipsen 2006), to 210 syllables for adult speakers, to much higher for academic lectures which use many multi-syllable words. We will try to convert 100 wpm into sps to determine what the ICAO is recommending.

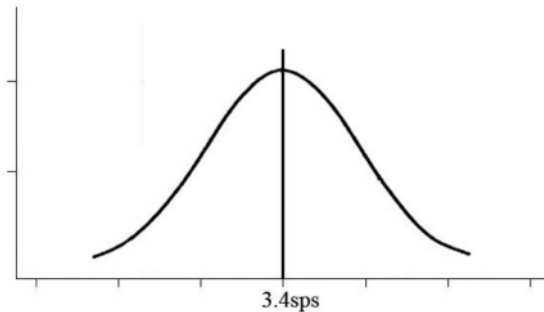
Spillers (2001) says that typical speech speed is 150 to 170 wpm, or 5-7 sps :

For American English speakers, we prefer information to flow between 150-170 words per minute (wpm). This number represents the rate of information flow. Some words are longer than others or have more sounds in them so we make tiny adjustments to our rate of speaking in order to maintain this constant rate of information flow. We can measure rate of speaking in syllables per second (sps). Most American English speakers speak at a rate of 5-7 syllables per second.

We found a median rate of 5.1 sps in movie speech. Taking Spillers' rate of 150 words per minute as equivalent to our median rate, we can calculate 100 word per minute as  $2/3$  of our median rate, or  $5.1 \times 0.66 \div 3.4$  sps. Taking a figure of 100 words = 210 syllables for adult speakers also produces a rate of  $210 \div 60$  seconds = 3.5 sps.

If we accept the calculation that 100 wpm = 3.4 sps, it seems that the ICAO is recommending 3.4 sps for ATC communications. As we found in our 2010a study, people do not speak at a constant speed but at a certain range of speeds. A median rate of 3.4 sps, therefore, might mean a distribution of speaking rates as shown in Figure 5.

From our listening study of 2010b, we found that 3.4 sps does



*Figure 5. Probable distribution of ATC speech recommended by ICAO.*

not pose any great problem for high level NNSE. We therefore do not suppose that NNSE pilots and ATCO should have any great problem at that rate, either. We can conclude that the ICAO recommendation for speech rate of 100 wpm, or 3.4 sps, is very reasonable, though rather slower than the median speech rate of 5.1 sps which we found in movies and slower than typical conversational speed of 5-7 sps. The Language Proficiency test speed of 4.5 sps can be considered as more than reasonable to evaluate listening ability, and perhaps even too fast.

However, we found that 6.1 sps was the median rate in actual ATC communications. We therefore see the need for pilots to be trained to cope with the actual situation, as the ICAO recommended speed rate is apparently much slower than what pilots face in reality.

## 5. Conclusion

In the present study, we calculated a median rate of speech of 4.5 syllables per second in the Language Proficiency Certification test for Japanese pilots as authorized by the Japanese Civil Aviation Bureau. This test was established to meet the International Civil Aviation Organization English language proficiency requirements at

Level 4 on a scale of 6 levels. The ICAO recommends a speaking rate in air traffic control environments of under 100 words per minute, which we estimate to be around 3.4 syllables per second. We conclude that the pilot test at 4.5 syllables per second meets the ICAO recommendations for speech speeds, and may even be faster than the recommended rate.

In a previous study, we calculated a median rate of 6.1 syllables per second in Air Traffic Control transmissions. In another study, we calculated a median rate of 5.1 syllables per second in popular Hollywood movies. We note that other studies report a typical median conversational speaking rate by native English speakers of about 5-7 syllables per second. We conclude that both the pilot test and the ICAO recommendations do not reflect typical speech speeds, but are instead rather slower, and, in the case of actual ATC communications, much slower.

Various standards like the pilot test and the ICAO recommendations have been established in order to measure and determine English ability; however, the scores obtained in such tests do not necessarily reflect listening and speaking ability in real-life situations. In another study, we determined that even non-native speakers of English with very high TOEIC® scores had great difficulty in hearing sentences in TV shows spoken at increasingly fast speeds. We suspect that, similar to the results of this study of high-level non-native speakers, pilots who have sufficient listening ability at 4.5 syllables per second will not be able to accurately hear words spoken at the real-life ATC rate of 6.1 syllables per second, and that even non-native speaking pilots with greater than ICAO Level 4 certification will encounter difficulties at higher speeds and will not achieve the same high listening ability results as native English speaking pilots. We note that we have received many anecdotal comments from experienced pilots expressing their concern over not being able to well-understand high-speed air traffic communications.

In listening to everyday conversation, missing or mis-hearing a few words in a sentence does not usually lead to terribly serious consequences; however, in Air Traffic Control situations, missing

words can be a matter of life or death. We hope to continue our research with a study of how the hearing ability of pilots changes at increasing speech rates in Air Traffic communications and what particular kinds of errors are involved, in order to contribute to the development of better training material and to safer air travel.

## Acknowledgment

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## Notes:

- 1) The ICAO describes its implementation of its Language Proficiency Requirements in ICAO (2004), and includes advice about dealing with language problems, and about language learning and teaching. Charts on pages 82-84 show the complete ICAO Language Proficiency Rating Scale from Levels 1-6 (Pre-elementary = Level 1, Elementary = 2, Pre-operational = 3 Operational = 4, Extended = 5, Expert = 6). A short introduction is available at <http://www.icao.int/icao/en/trivia/peltrgfaq.htm#29>
- 2) For example :  
 TWR: *"Yes sir you can uh bypass that first high speed for \*\* fifty five twenty four."* = 4 sps.  
 TWR: *"\*\*\* twelve eighty eight wind calm runway one right cleared for takeoff."* = 5 sps.  
 TWR: *"\*\*\* three forty three San Francisco tower good morning runway two eight right cleared to land winds calm"* = 6 sps.  
 TWR: *"Who was that calling?"* = 7sps.  
 TWR: *"\*\*\* three eighty two continue reducing a \*\*\* will depart prior to your arrival."* = 8 sps.  
 For this article, aircraft IDs have been replaced with asterisks (\*\*\*) to avoid invasion of privacy.  
 One asterisk = one syllable.
- 3) The movies analyzed and their median rates of speed in order of increasing speed were : *Ratatouille* (animation movie) = 4.3 sps, *Monsters Inc* (animation movie) = 4.6 sps, *Roman Holiday* = 4.7 sps, *The Hours* = 4.9 sps, *Out of Africa* = 4.9 sps, *Full House* (TV drama) = 4.9 sps, *Sex and the City* (TV drama) = 5.0 sps, *The Seven Year Itch* = 5.1

sps, *The Bourne Identity* = 5.2 sps, *Columbo* (TV drama) = 5.3 sps, *Back to the Future* = 5.3 sps, *Legally Blonde* = 5.3 sps, *A Beautiful Mind* = 5.4 sps, *The Apartment* = 5.8 sps.

- 4) For example : *I do not want her babysitting our child.* = 4 sps.  
*I never should have broken up with you because you were overweight.* = 5.2 sps  
*You don't make a very good first impression.* = 6.2 sps  
*He's never gonna tell her how he feels about her.* = 7.1 sps  
*Because I think I just heard her moving around in there.* = 8.2 sps

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## Appendix

The Ministry of Land, Infrastructure, Transport and Tourism has made past tests available to the public through their web site. However, the dialogue texts are not available. The dialogue below is Dialogue Number Three which we transcribed from the sound file of the July 2011 test.

ATC: JA07JB, this is Kushiro tower. We found some tire chips on the runway after your takeoff. Was your takeoff normal?

Pilot: JA07JB, Thank you for your advice. We experienced vibration during takeoff roll. It appears to be a tire burst. Request proceed to the downwind. Also request low pass with tower checking our gear condition.

ATC: JA07JB, understood, left downwind approved. Proceed to left downwind, JA07JB.

ATC: JA07JB, runway 35, cleared low approach, wind calm. We will check your gear condition.

Examiner's Voice: Answer questions 7 to 9.

Question 7. Kushiro tower found the rubber chips ...

1. before JA07JB's take-off roll.
2. during JA07JB's take-off roll.
3. after JA07JB lifted off.
4. during JA07JB's downwind leg.

Question 8. JA07JB experienced ...



1. vibration.
2. broken windshield.
3. low hydro pressure.
4. engine failure during takeoff.

Question 9. JA07JB asked Kushiro tower to observe the ...

1. flaps condition.
2. wind condition.
3. landing gear.
4. tire chips on the runway.